HUMAN FACTORS ASPECTS IN A LEVEL IV VESSEL TRAFFIC SYSTEM OPERATIONS CENTER

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THESIS

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by

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Human Factors Aspects In A Level IV

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ABSTRACT

This paper constitutes an investigation of human factors in U.S. Coast Guard operated vessel traffic system operations center in general and the San Francisco center in particular. Research involved in preparation of this thesis was accomplished by measurement, observation, job analysis by operational personnel and review of applicable human factors literature. These research steps resulted in a description of the operating system, task capability requirements, task-induced-demand analysis and comparison of the physical environment with published literature. Human factors aspects of the system having probable or possible detrimental effects on system effectiveness are pointed out, and quantified where possible. Experimentally proven steps to relieve these effects are presented as an aid for operational systems and designers of future systems.

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I. INTRODUCTION

The U S. Coast Guard has been designated by the Ports and Waterways Safety Act of 1972 as the federal agency under the Secretary of Transportation to "establish, operate, and maintain vessel traffic services and systems for ports, harbors, and other waters subject to congested traffic."[1]

To this end, the Coast Guard has designed control systems consisting of varying mixes of facilities, sensors and personnel. Prototype systems of differing complexity, cost and legal control are operating in two harbors, with another in the process of installation. Results of efforts in research and practical application are summarized in the Coast Guard document Vessel Traffic Systems Issue Study [1973]. "Handling human factors in developing system." is listed as Task 6.2.6 in the study plan outline in this document. This area was not covered in the published document.

The thesis of this paper is that there are human factors aspects of Vessel Traffic System operation that should be considered in the design and operation of such a system. The approach to this thesis was specification and analysis of the external and internal environment of a particular system, the San Francisco Vessel Traffic System. Specification of the system was accomplished in this study by development of a system description. The analysis phase of the study falls into two major divisions. System Activity

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[1] "Ports and Waterways Safety Act of 1972," H.R. 8140, Public Law 92-340, July 1972.

Analysis was accomplished by analysis of an observation-generated questionnaire given to personnel in the Vessel Traffic System operations center. Information for literature comparision was gained through observation and measurements conducted in the Vessel Traffic System operations center. By this process, conclusions based on current literature in the human factors field and recommendations for future application were drawn.

Appendix A contains Coast Guard definitions of Vessel Traffic System terms and abbreviations useful to the reader U.S. Coast Guard [1973].

II. SYSTEM DESCRIPTION

A Vessel Traffic System (VTS) can best be described as a mix of active, advisory and passive management plans designed to decrease the probability of large-vessel caused catastrophies in the marine environment. Implementation of these plans involves technologies ranging from simple buoy systems to Computerized Collision Avoidance Systems employing high resolution radars as sensors. In all systems, with the exception of passive or regulatory management, a VHF-FM communications network links vessels with a control facility. This facility, the Vessel Traffic Center (VTC) is the operational heart of the system. Inputs from sensing devices, the Vessel Movement Reporting System (VMRS) and various externally and internally generated status information are analyzed by VTC personnel. This interaction of men and information is the process which satisfies the objectives of vessel traffic management.

The information analysis process results in real time information for users of the system. This information serves to increase the time available for making decisions, decrease the number of decisions to be made and decrease the complexity of decisions required of the master or pilot on a vessel. These points of advantage to the user match the Coast Guard System objectives [U.S. Coast Guard 1973].

A VTS is composed of sub-systems designed to manage marine traffic in a sector of the system coverage area. Each sub-system has a monitor or Sector Controller who directly accomplishes the bulk of the VTC functions for

his assigned sector. The controller is assisted by a supervisor in the decision making process resulting from information analysis.

The system description to this point is applicable to all VTC. Objectives, external inputs and mangement organization are common to all active and proposed federal systems.

The San Francisco VTS is presently classified as a Level IV system. This level includes regulatory Traffic Separation Schemes (TSS), a required VMRS, high resolution radars as active vessel-position sensors, a VTC, and the capability of positive regulation of vessel separation and speed within the radar coverage area [U.S. Coast Guard 1973].

A. EXTERNAL ENVIRONMENT

The operating environment of San Francisco VTS consists of around the clock specified user vessel traffic on the waters and approaches of San Francisco Bay. High resolution radar coverage and VRMS provide VTC inputs from the bay and the Pacific Ocean approach. Vessels approaching the bay from the North are under advisory VRMS management. Additional VTC inputs regarding weather, planned vessel movement and navigation hazards are acquired through teletype, telephone or newspaper media. Emergency and Coast Guard communications frequencies are standard for all units in the service.

Sensor performance is limited by geographical configuration and meteorological conditions of the coverage areas. Blind spots in radar and radio coverage are minimized by use of multiple transmitter-sensor sites. Radar coverage area performance with high resolution radar suffers only slightly from sea return and inclement weather conditions.

B. INTERNAL ENVIRONMENT

The sensors, transmitters and other inputs link the external environment of the VTS to the internal environment, the VTC. The inputs take on visual or auditory form for information analysis by the sector controllers and supervisor staffing the center (Figure 1A).

San Francisco VTC is operationally staffed by four men, three controllers and a supervisor. The three basic control regions are: (1) Pacific Ocean Approach, (2) Bay Radar Coverage Zone, (3) Northern Approaches to the Radar Coverage Zone.

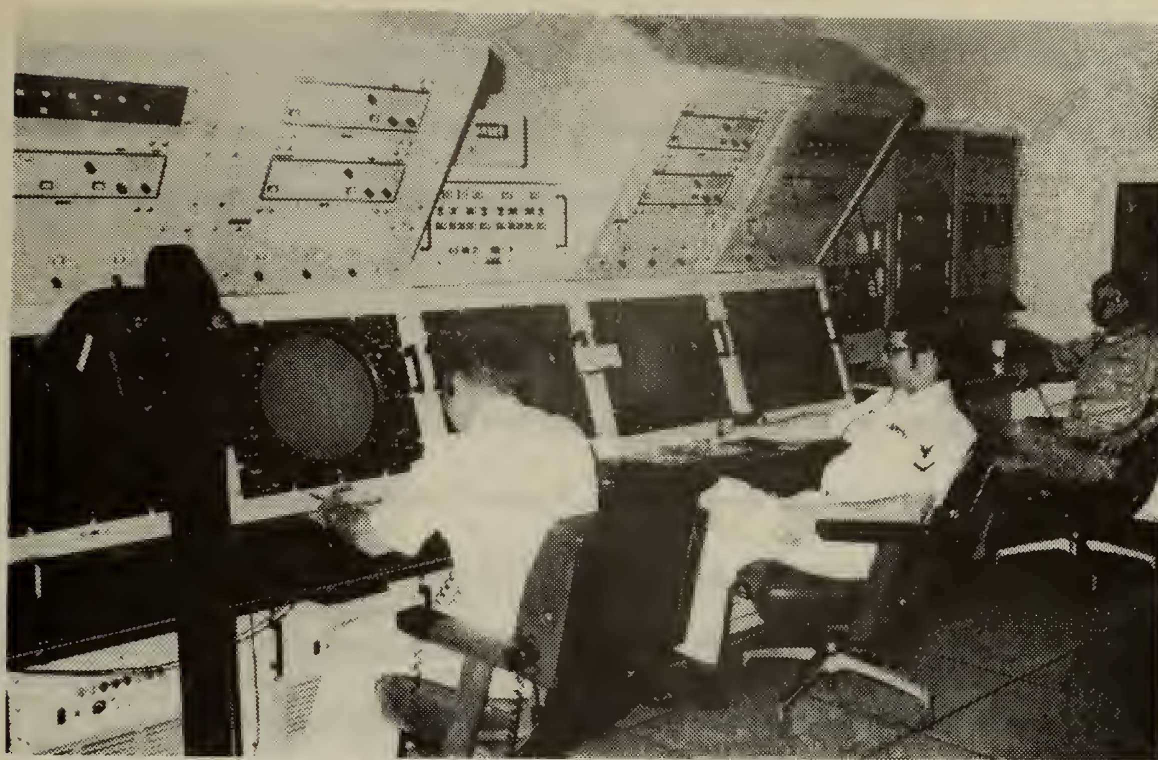
1. Information Display

The Pacific Approach and Bay Sector Controllers man positons at offsettable planned position indicator radar displays. All controllers maintain radio communications via headsets on assigned frequencies with user vessels operating in their sectors. Remote sensing equipment, microwave links and visual or auditory output equipment are duplicated throughout the system for high reliability.

Other external information is provided for all personnel either at their position in written form or displayed on an internally illuminated wall chart of the VTS area (Figure 1B).

2. Information Processing

The VTC is essentially an information processing unit. Externally generated information and conditions are evaluated in light of the stated VTS objectives and existing regulations. Appropriate action is determined through this evaluation. This action may range from none at all for a non-



1A. Sector Controller Positions, VTSSF. (U. S. Coast Guard Photo)

1B. View from Supervisor Position Toward VRMS Panel, VTSSF. (U. S. Coast Guard Photo)

Figure 1

pertinent input to positive control of vessel traffic in a restricted passage zone or imminent-catastrophe circumstances. The assigned task of each man in the VTC reduces to optimum information processing.

To accomplish this assignment, skills in communications, equipment operation, display monitoring and evaluation, and decision processes are required. Skill levels in the latter two areas were acquired by observed controllers and supervisors through on site and on-the-job training. This type of training was determined by executive personnel to be best suited to the task due to the unique characteristics of any one particular coverage area.

Evaluations leading to positive action in a sector are referred to the supervisor for further evaluation and decision processes. This process can occur by verbal communication between the controller and supervisor or via oneway intercom to the controller from a supervisor acting on monitored sector frequency information.

a. Internally Generated Information

Data generated by controller communications with user vessels is recorded on blank computer cards in script. Portions of this data indicate future required action by the controller. The cards become a working part of the controller information system until action is required or the user vessel crosses into another sector. Examples of required action are an apparent deviation from recorded destination information or checking the user vessel out of the VTS. Monitoring this information source and the skill of relating the information contained on the cards and the information on other displays, particularly a radar, are functional activites of the controller.

A second source of internally generated information to a controller is passed information, the verbal and written card communication accompanying a user vessel entering his sector from another. The receiving controller adds this new information to his information system and proceeds with the processes outlined in the previous paragraph.

3. Decision Processes

Outputs, or action by the VTC, are a direct result of decision processes rooted in prior evaluation. VTC outputs through controllers take the form of advisory messages with pertinent user vessel information or the active mangement mode in which action is required of the user vessel. Other outputs include specified data and Captain of the Port message activity. Normal responses to routine communications require decision activity from the controller only.

a. Internally Processed Decisions

Outputs at the internal level consist of information and card passing to adjacent sectors, controller-supervisor communication and social conversation between VTC personnel.

4. Ambient Working Conditions

a. Illumination

Ambient lighting in the VTC was provided by the internally illuminated VTS area and information display panel. Lighting at the northern approach VRMS position was accomplished by a flourescent desk lamp. The supervisor used a Diax Model Tensor High Intensity Lamp at his position. Other light sources observed were radar signals and hallway light when the VTC door was opened. There are no windows in the VTC.

b. Noise Levels

Observed noise was generated by the radar equipment, radio communications, and personnel conversation.

c. Shift Lengths

Maximum shift lengths for on-duty and at a radar position were set by regulation at twelve hours and two hours, respectively. Continuous time off was similarly set for minima of twenty-four hours per week and a thirty-six hour period each month. One hour of relief from the radar position was required for each two hours at the console.

d. Control Operations

Radio transmission was accomplished by a step-on bar-key. Controls for shifting communication frequencies or transmission towers were located above the radar positions for approach and bay controllers. Communication controls for the northern approach sector were located above the desk at the controller's position.

Operator radar controls were attached to the radar console with the exception of the off-setting range track ball built into the shelf of the operator console.

e. Equipment Layout

Overall equipment layout was observed. The amount of space available for equipment and personnel with respect to room size was not observed.

III. SYSTEM ACTIVITY ANALYSIS

To examine the nature of the man-machine interface in vessel traffic control, it was helpful to describe the controller's tasks in terms of capabilities required to perform them. Table I is based on an analysis of the human factors literature and provides a list of the human capabilities required in vessel traffic control. The list encompasses essentially all of those skills a trained and qualified controller must possess in order to perform successfully the various activities required for vessel traffic control.

Using the list in Table I as a guide, a list of the observed activities of operational controllers was devised. Each activity, not surprisingly, can be classified by one or more of the capability categories.

Forms[2] calling for relative ranking of skills in terms of importance and strict ranking of activities were given to all qualified controllers at VTC San Francisco. Activities were to be ranked in order over three task dimensions in order to get a quantitative "feel" for the demandingness of each a activity on the capability of the controller. Each subject was to rank the controller's activities based on his operational experience as a controller, irrespective of primary duties. The three task dimensions were defined [Older and Cameron 1970] as follows:

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[2] Sample forms contained in Appendix B.

TABLE I

Descriptions of Human Capabilities

1. Visual Monitoring-Display: To attend to a continuously changing visual information source and report system status on request.

2. Visual Monitoring-Nondisplay: To attend to a continuously changing visual information source and report system status on request.

3. Auditory Monitoring: To attend to a continuously changing auditory information source and report system status on request.

4. Recording: The preparation of written messages, information and reports.

5. Reporting: Transmitting oral messages, information, and reports.

6. Control Operations: Applying manual force to equipment or controls once a response has been selected and a decision to act has been made.

7. Information Organization: The evaluation, synthesis, and integration of information from varied visual or auditory sources.

8. Selecting Among Alternatives: Predicting, on the basis of all available information, which of a number of alternatives optimizes system function.

9. Information Storage: The short-term retention of recently acquired material-information subject to immediate recall..

Difficulty - The extent to which the activity requires training and experience for adequate performance.

Restrictiveness - The amount of attention the activity requires of a controller, thereby restricting his ability to perform other activities at the same time.

Stressfulness - The extent to which an activity induces a sense of subjective strain.

Ratings for capability requirements and each of the three activity dimensions were made consecutively and independently by the subjects. These ratings were then combined for information on skill requirements and the demand placed on the controller by activites. Results were calculated for the controllers according to pay grade in three categories: Officers who function as supervisors, Chief Petty Officers (CPO), enlisted grades below Chief Petty Officer. Differences in background, maturity and responsibility prompted this categorization by grade for the qualified controllers. For example, the Chief Petty Officers (CPO) as a group had more background in similar tasks than either the officers or lower grade enlisted personnel, but carried less overall responsibility than the supervisory officers.

A. CAPABILITY REQUIREMENTS

Quantitative results of the relative ranking of skill or capability requirements of the radar controller positon are shown in Figures 2 and 3. Figure 2 illustrates the results of the relative ranking process for nineteen qualified controller subjects. Figures 3 illustrates the variation due to groups, by grade.

B. TASK DEMANDINGNESS

Tables III through VI illustrate the overall activity demand on the controller's capability, the difficulty, the restrictiveness and the stressfulness

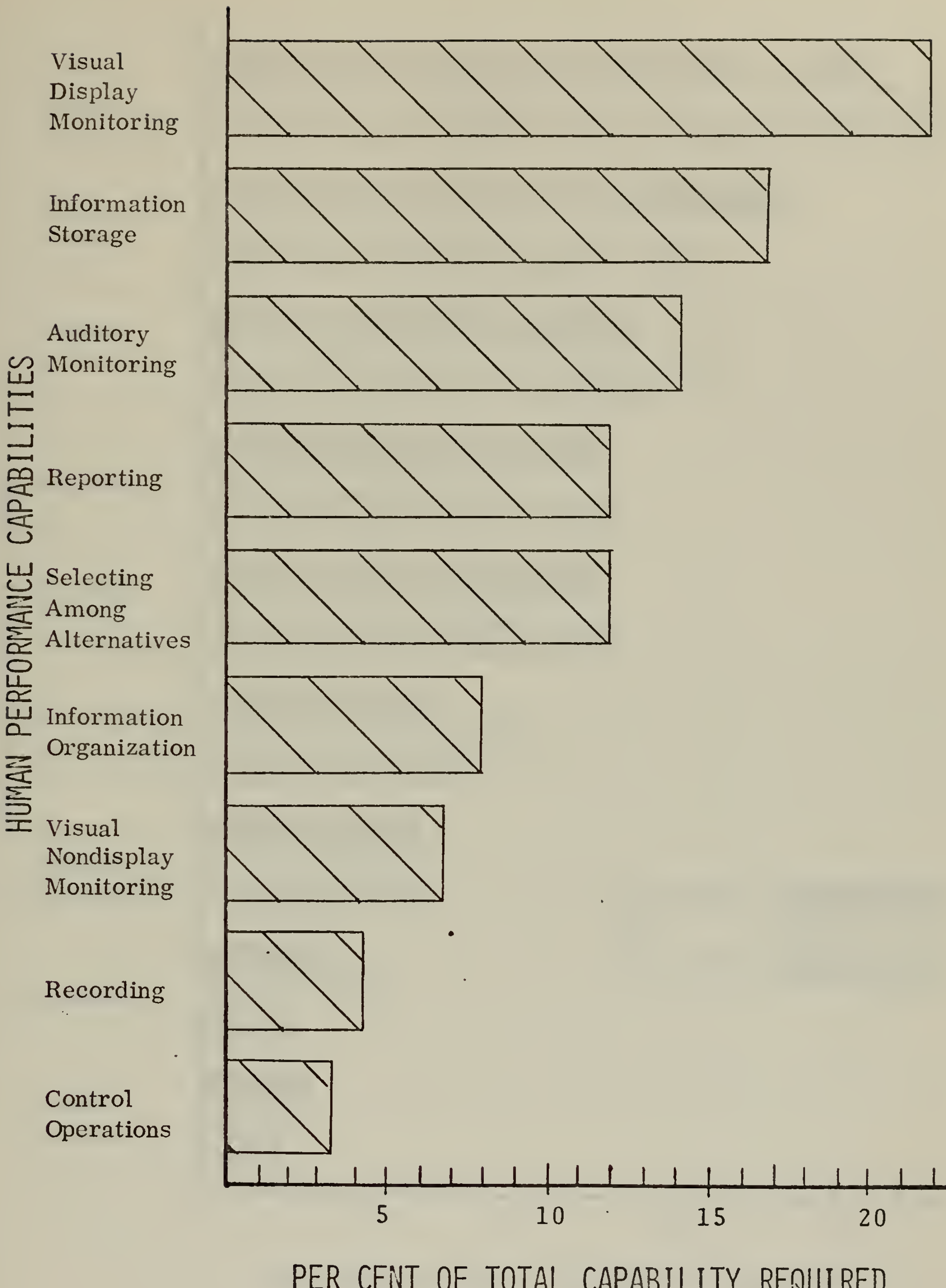
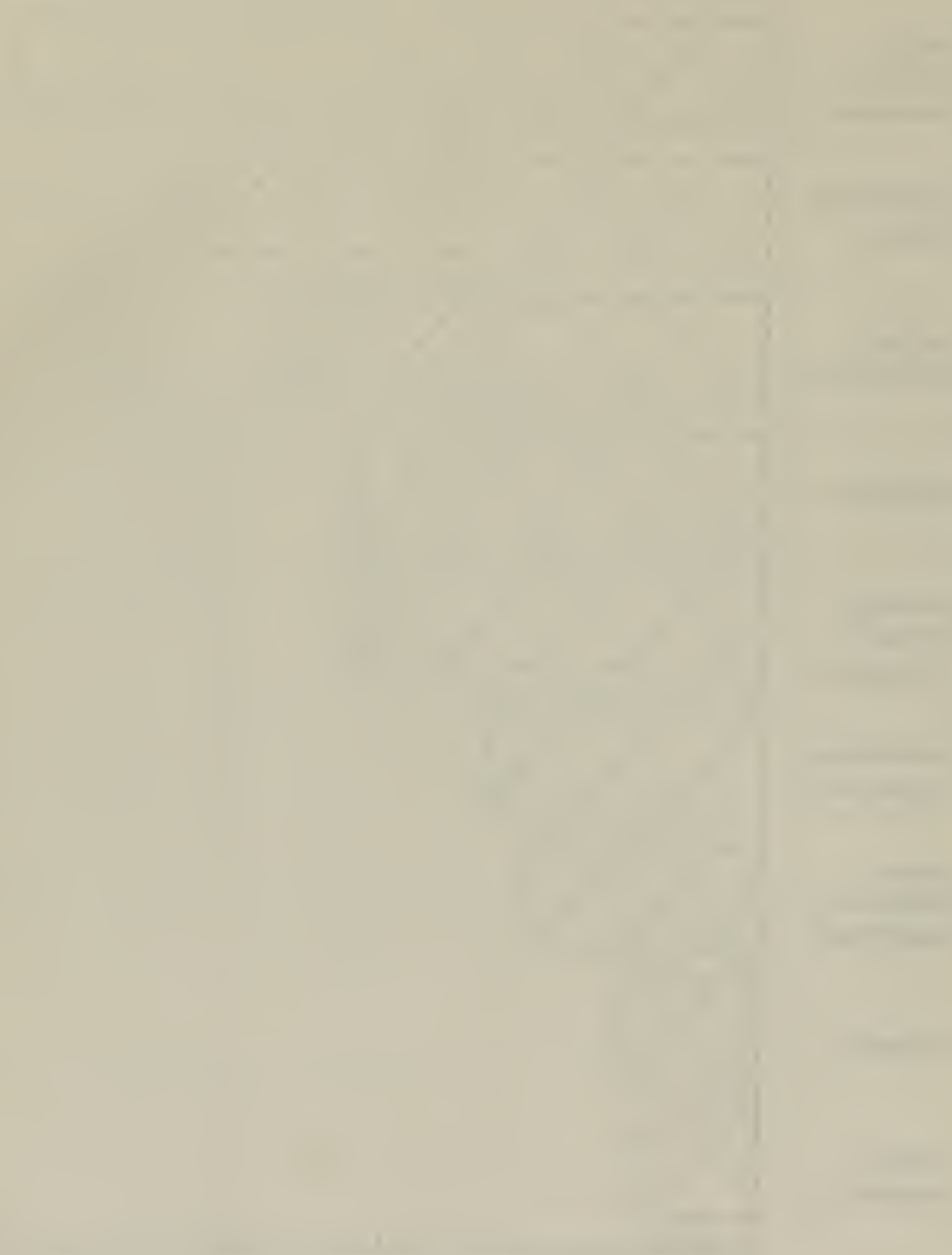


Figure 2

Human Capabilities Required, All Grades



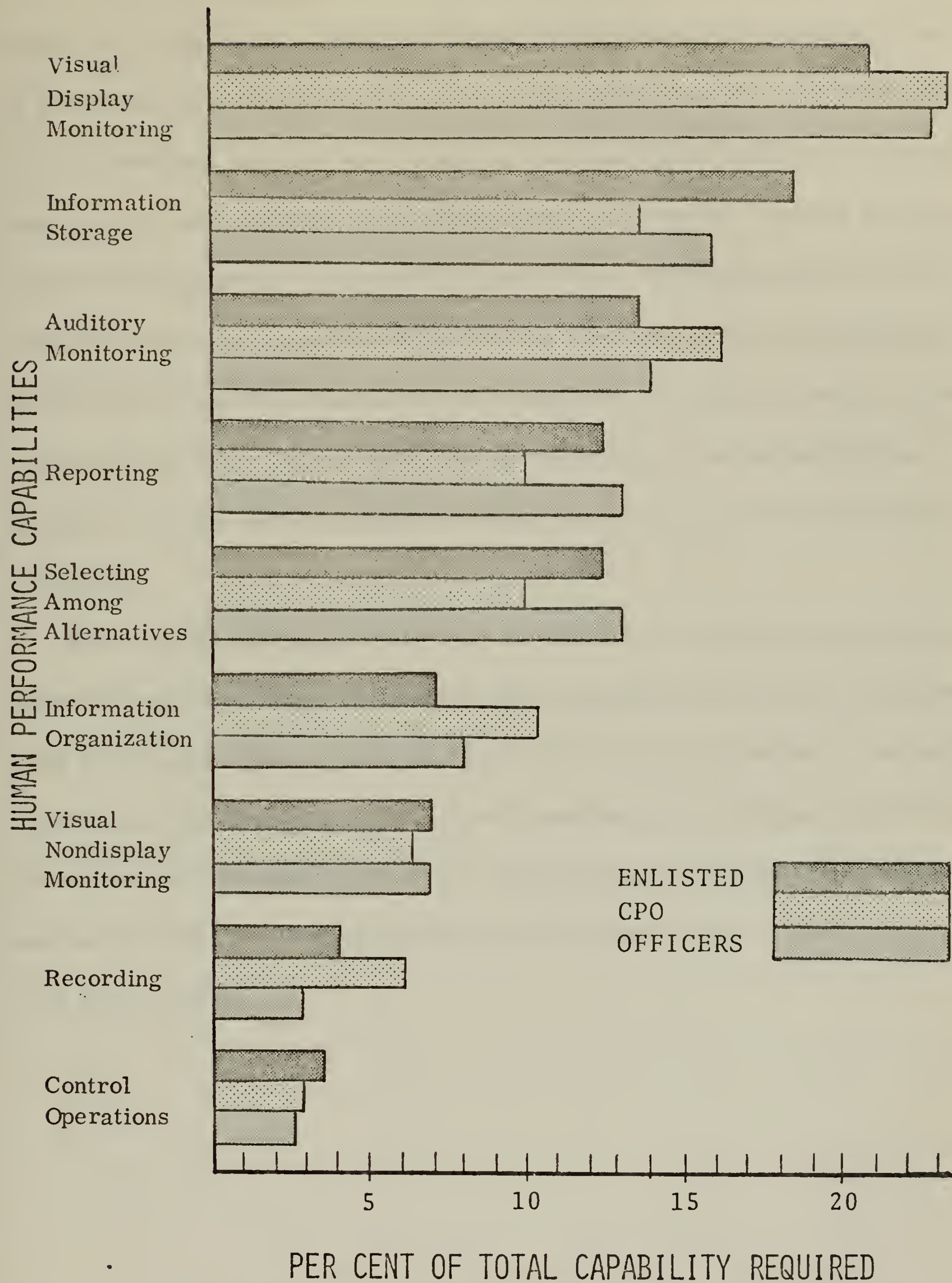


Figure 3
Human Capabilities Required, By Grade

ratings for all subjects. Figures 4 through 7 illustrate the variation in each of these task dimensions by pay grade and number in each group participating. Group dimension rankings were made by subtotaling the assigned individual rankings for each activity, then ranking these subtotals. Overall dimension ranking was obtained by an identical procedure, totaling group subtotals. Demandingness was determined by totaling the numerical group subtotals of each activity over the dimensions and ranking on the basis of activity grand totals. Chief Petty Officer data was not included in the demandingness ranking, as there were no responses from this group on the stressfulness dimension.

Rank-order correlation tests were conducted to determine if differences between Non-Chief Petty Officer enlisted controllers and officer controllers were significant. The hypothesis tested was the null hypothesis, or no difference between the categories. This hypothesis was rejected at the 0.01 level of significance with a Spearman Rank-Order Correlation Test (rho=0.704) and at the 0.001 level of significance with a Kendall Rank-Order Correction Test (tau=0.522).

TABLE II

Ranking of Section Controllers Activities in terms of Task Demandingness, All Grades

Activities	Rank
1. Operate Radar Equipment	14.0
2. Read Radar Display	2.0
3. Interpret Radar Display	1.0
4. Record Card Data	8.5
5. Use Cards as Action Initiators	7.0
6. Relate Cards to Radar Display	8.5
7. Passing Information/Cards to Next Controller	11.0
8. Review Weather and Notice to Mariners (Status)	15.0
9. Operate Radio Equipment	13.0
10. Keep Supervisor Informed on Developments	12.0
11. Memorization of Information	10.0
12. Answering Information Querys	3.5
13. Initiating Advisory Messages	3.5
14. Control Restricted Area Traffic	6.0
15. Monitor the Control Frequency	5.0

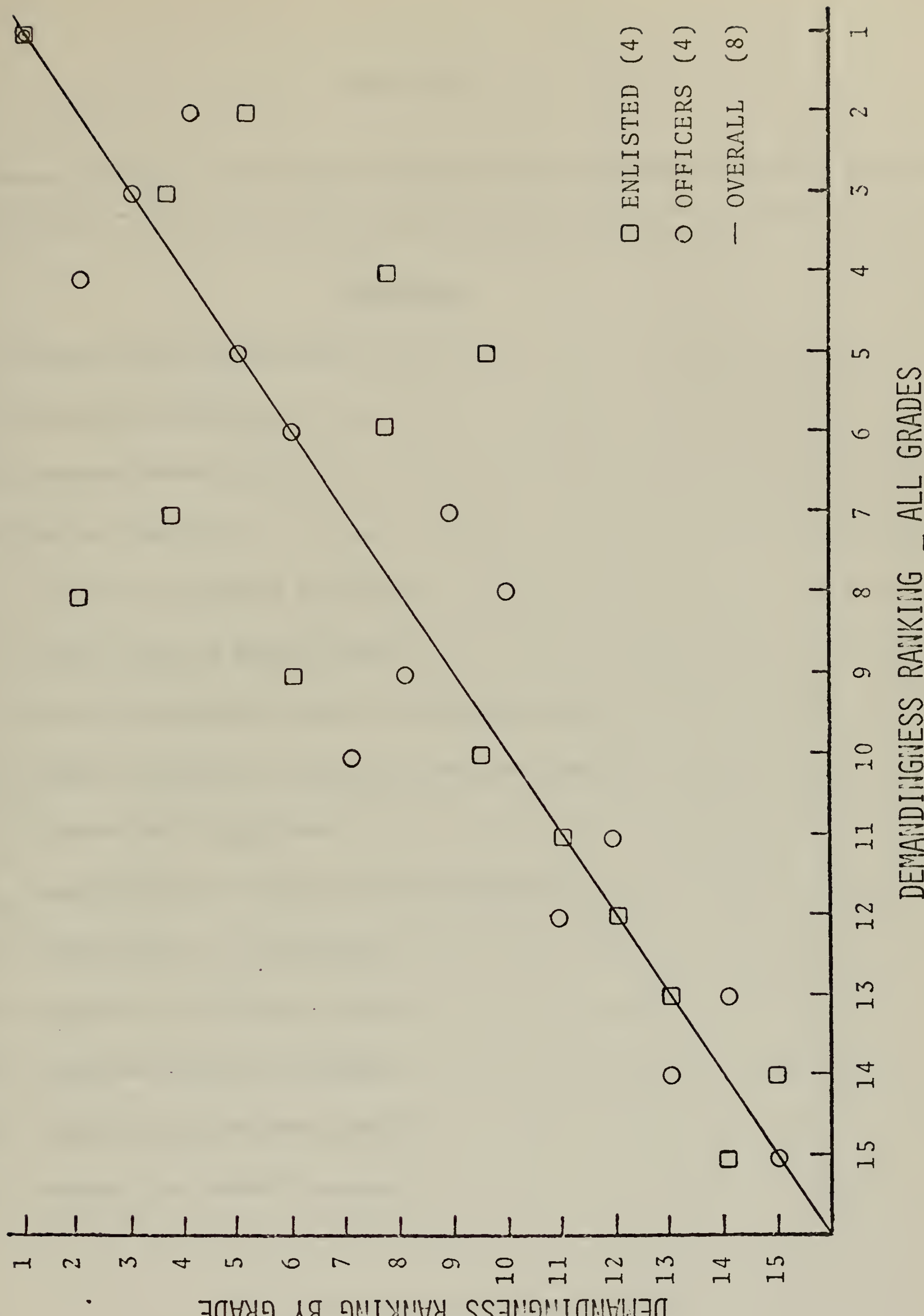


Figure 4
Task Demandingness Ranking, By Grade

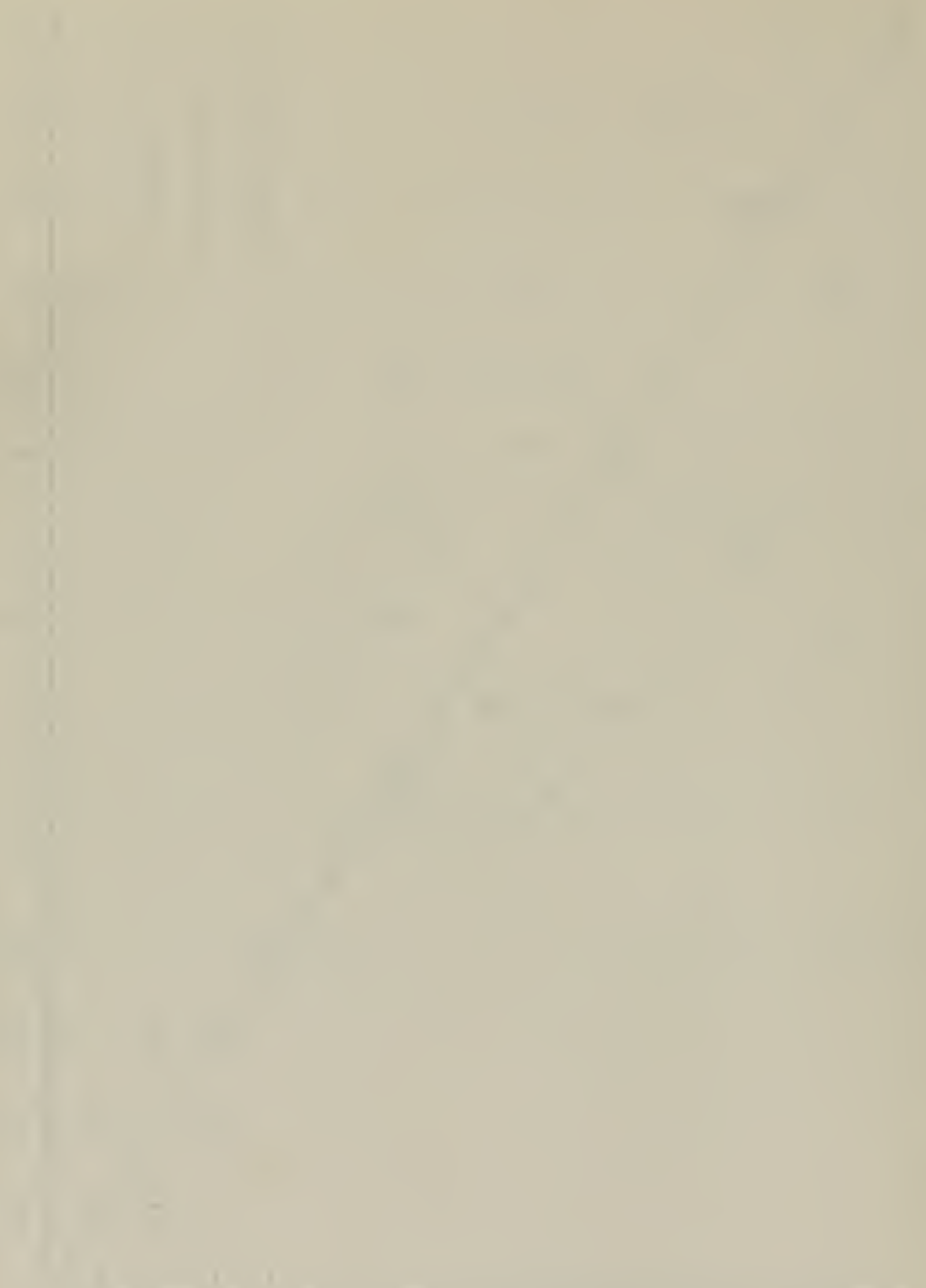


TABLE III

Ranking of Sector Controller Activities in Terms of Task Difficulty, All Grades

	Activities	Rank
1.	Operate Radar Equipment	13.0
2.	Read Radar Display	2.0
3.	Interpret Radar Display	1.0
4.	Record Card Data	9.0
5.	Use Cards as Action Initiators	8.0
6.	Relate Cards to Radar Display	5.0
7.	Passing Information Cards to Next Controllers	14.0
8.	Review Weather and Notice to Mariners Status	15.0
9.	Operate Radio Equipment	11.0
10.	Keep Supervisor Informed on Developments	12.0
11.	Memorization of Information	3.0
12.	Answering Information Querys	6.0
13.	Initiating Advisory Messages	7.0
14.	Control Restricted Area Traffic	10.0
15.	Monitor the Control Frequency	4.0

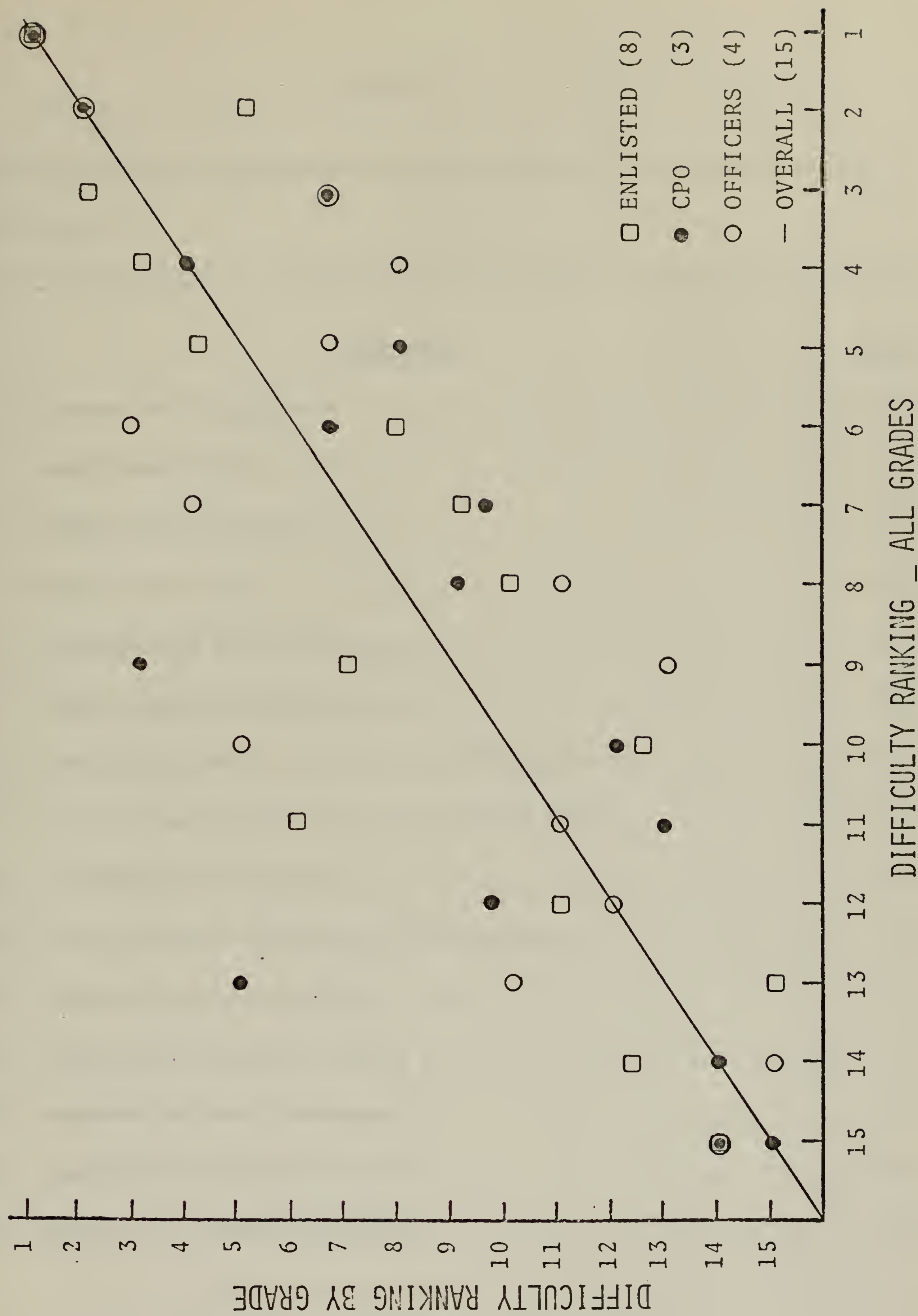


Figure 5
Task Difficulty Ranking, By Grade

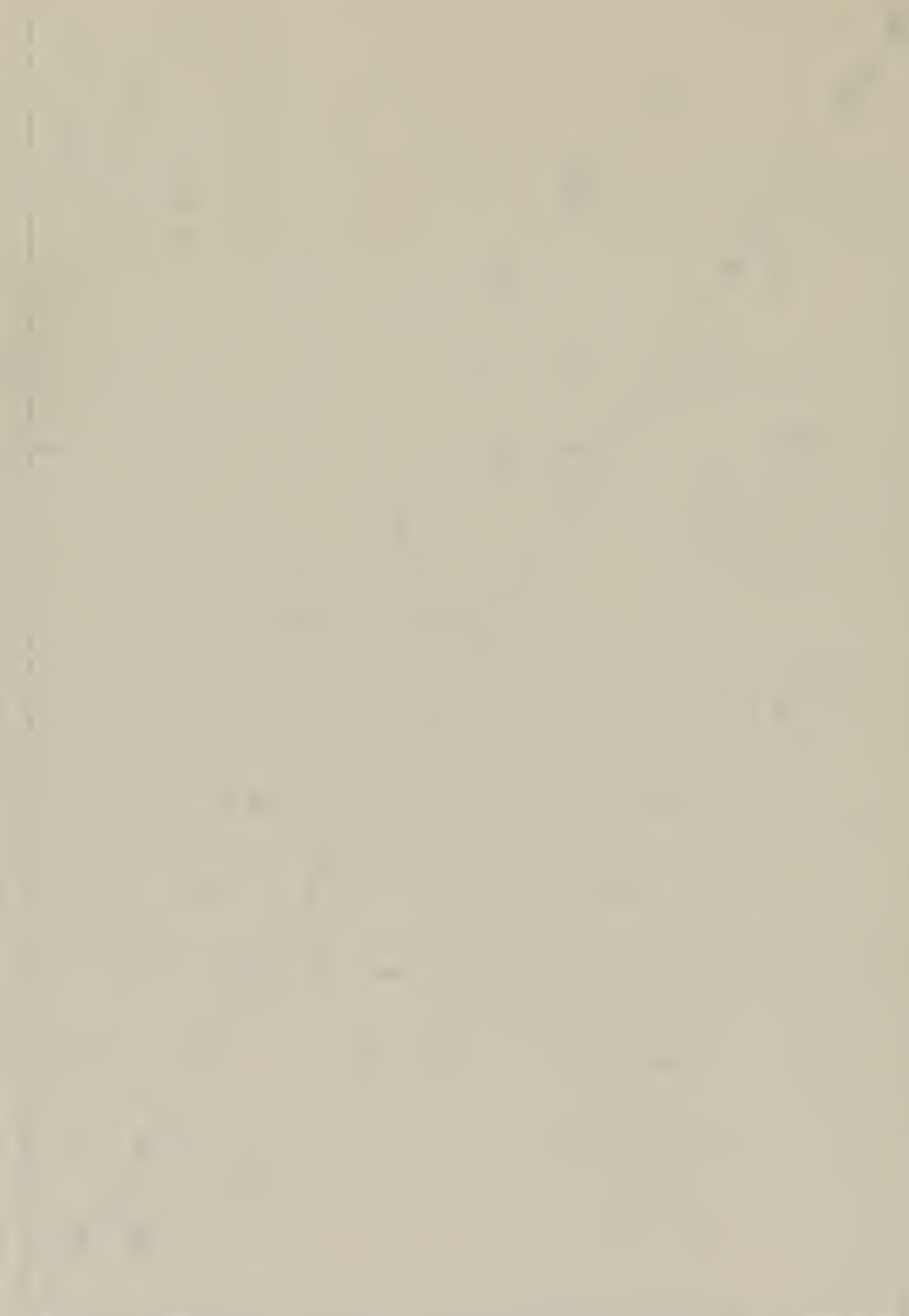


TABLE IV

Ranking of Sector Controller Activities in Terms of Task Restrictiveness, All Grades

Activities	Rank
1. Operate Radar Equipment	13.0
2. Read Radar Display	2.0
3. Interpret Radar Display	1.0
4. Record Card Data	4.5
5. Use Cards as Action Initiators	8.0
6. Relate Cards to Radar Display	7.0
7. Passing Information Cards to Next Controllers	15.0
8. Review Weather and Notice to Mariners Status	14.0
9. Operate Radio Equipment	12.0
10. Keep Supervisor Informed on Developments	11.0
11. Memorization of Information	10.0
12. Answering Information Querys	6.0
13. Initiating Advisory Messages	3.0
14. Control Restricted Area Traffic	9.0
15. Monitor the Control Frequency	4.5

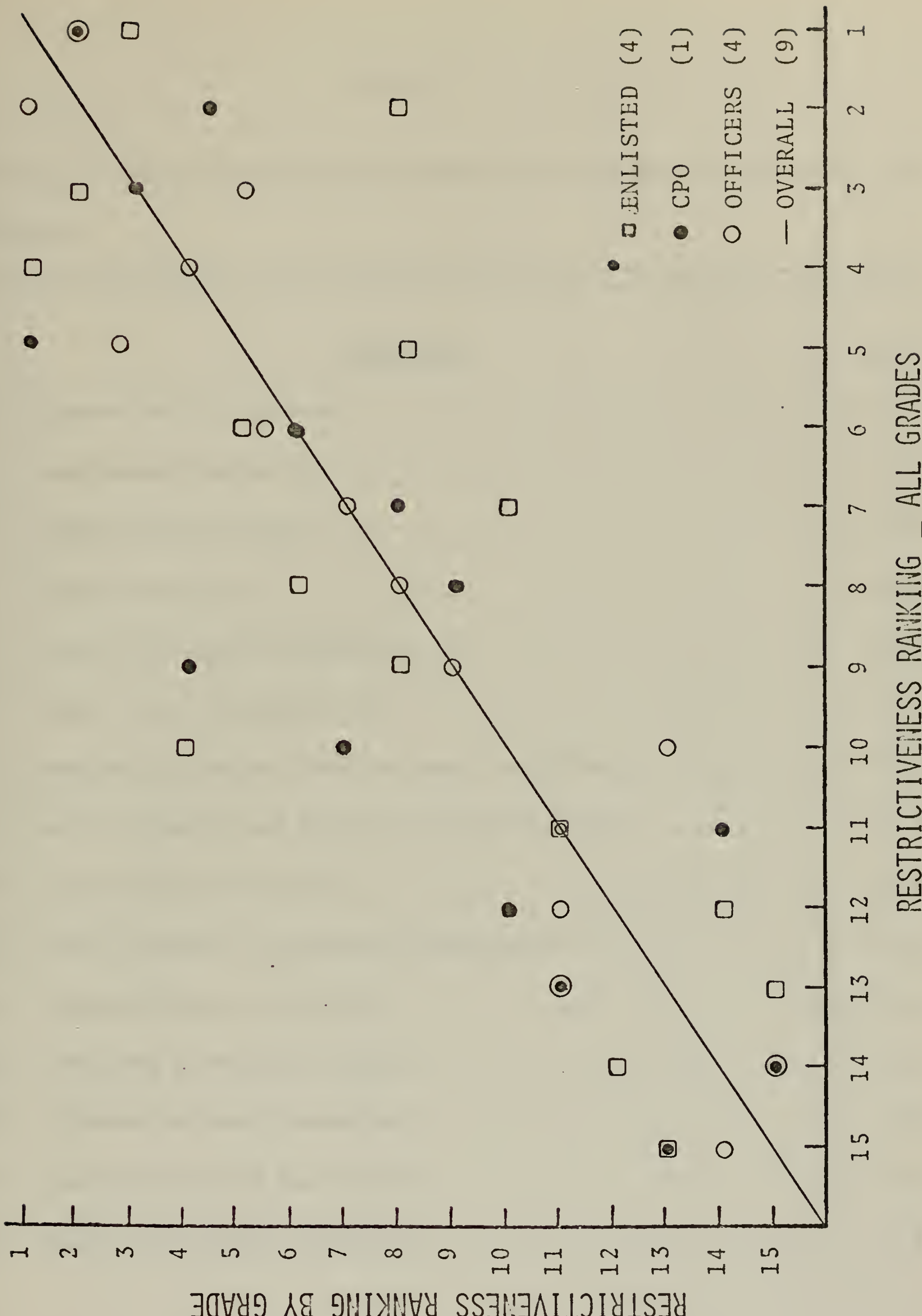


Figure 6

Task Restrictiveness, by Grade

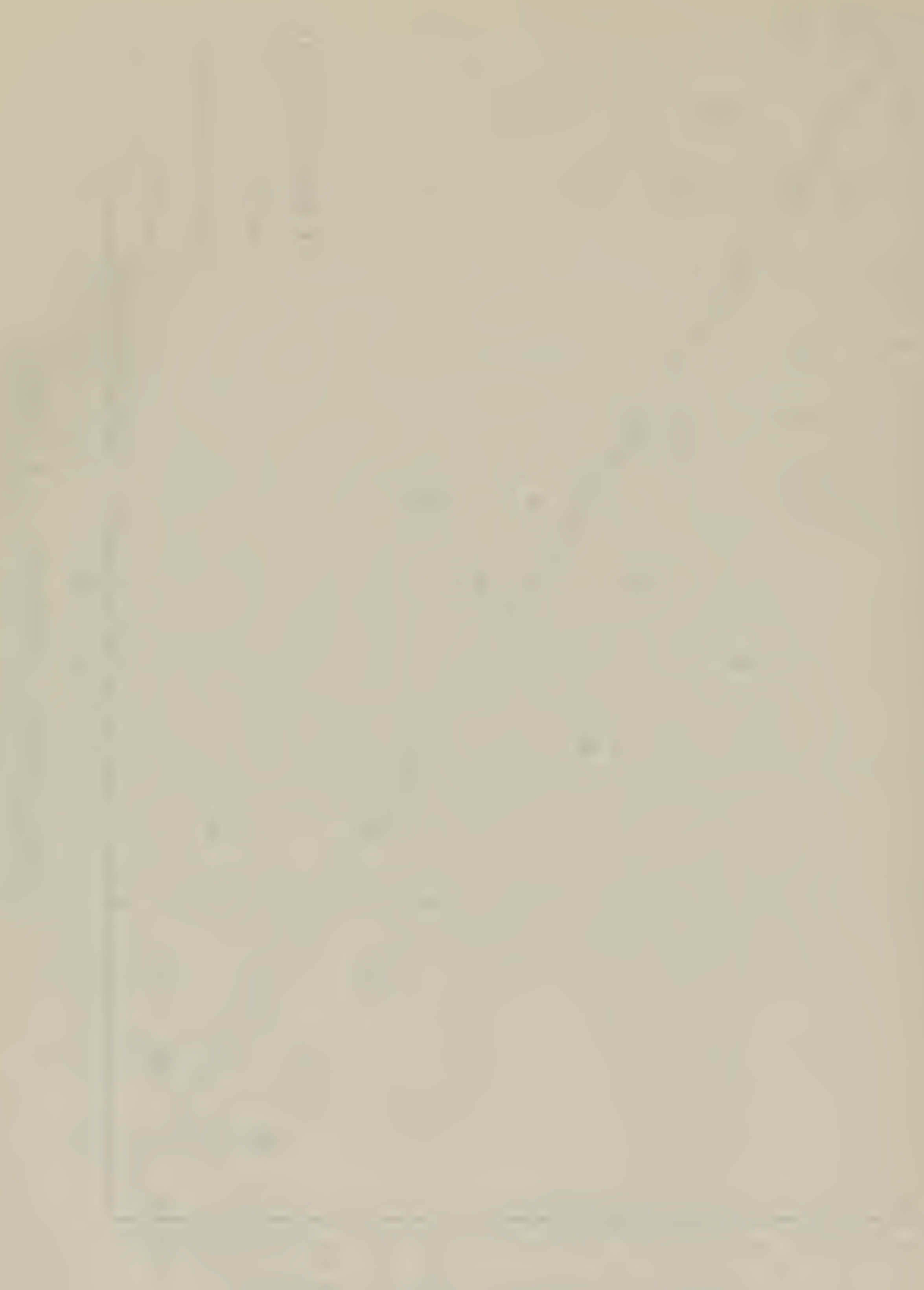


TABLE V

Ranking of Sector Controller Activities in Terms of Task Stressfulness, All Grades.

Activities	Rank
1. Operate Radar Equipment	15.0
2. Read Radar Display	6.0
3. Interpret Radar Display	3.0
4. Record Card Data	8.0
5. Use Cards as Action Initiators	5.0
6. Relate Cards to Radar Display	9.5
7. Passing Information Cards to Next Controllers	12.0
8. Review Weather and Notice to Mariners Status	14.0
9. Operate Radio Equipment	13.0
10. Keep Supervisor Informed on Developments	11.0
11. Memorization of Information	9.5
12. Answering Information Querys	2.0
13. Initiating Advisory Messages	4.0
14. Control Restricted Area Traffic	1.0
15. Monitor the Control Frequency	7.0

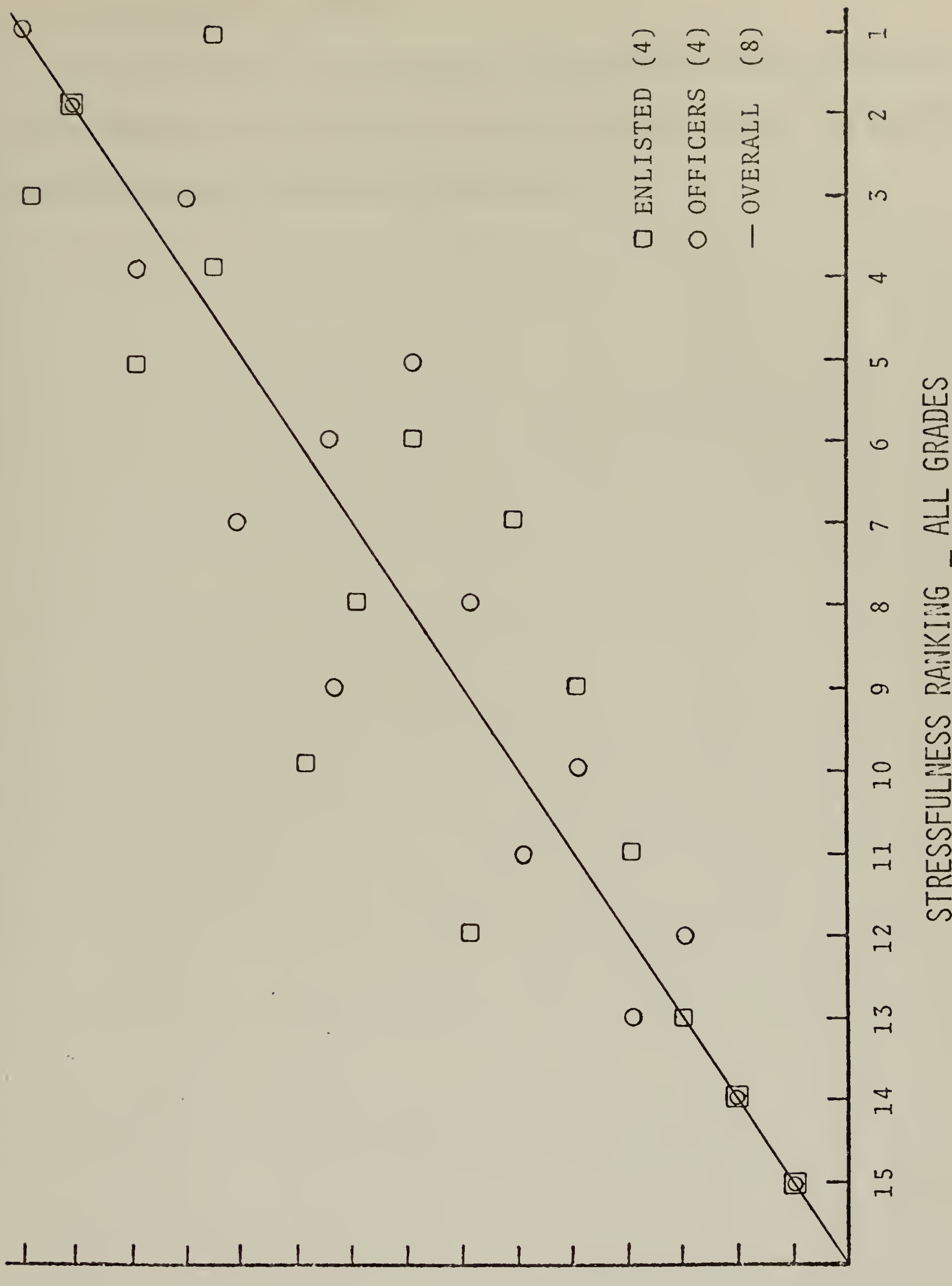


Figure 7
Task Stressfulness Ranking, By Grade

C. CONTROLLER COMMENTS

Table VI provides an incomplete but representative list of comments made in response to a questionnaire given to the subjects with the capability and task dimension ranking forms (Appendix B).

TABLE VI

Sample Comments on Problems by Qualified Controllers

1. To eliminate the use of the cumbersome cards on such a narrow desk....

2. Also smoke filled rooms make me sluggish.

3. Light level in operations center should be further reduced.

4. Reduce to one man operation of radar operator/communicator.

5. Increased effectiveness could be most easily achieved by relieving operator boredom.

6. Reduced candle power from the VRMS display would increase effectiveness.

7. Lack of ventilation (exhaust) in center.

8. Redesign communication system controls to parallel system in synthetic display console.

9. Installation of TV camera system @ YBI and Alcatraz as a tool for evaluating pleasure boat concentrations.

10. Operator boredom.

11. Communications control panels. Same capabilities could be packaged into 1/50th of space of present set up.

12. Relocate and simplify communications equipment.

13. Reduce the number of distractions around the operator.

14. Reduce the importance of the cards and come up with a better method of showing a vessel's information.

15. There is no ventilation in Operations Center. Smoke accumulates. Irritates eyes and nose. Effects (sic) my capability.

IV. MAN-SYSTEM INTERFACE

The system description delineates the functional man-system interface of the radar position controller through observation. The system activity analysis points up functional areas of that interface which were considered important by the controllers themselves. This section will, through human factors analysis of VTC ambient working conditions, relate the system description and activity analysis. The work presented here is intended to show the importance of a human engineering approach to system design. A model of the functional and ambient environment of the radar controller is shown in Figure 8.

A. ILLUMINATION

As stated in the system description, the lighted panel to the left of the controllers provided the ambient lighting for the VTC. Ambient light level was understandably low in view of the radar monitoring function. This policy is supported by Morgan, et. al. [1963] and Woodson and Conover [1964]. The light providing panel, however, deviated from these authors and Grandjean [1971] concerning both type and placement of the illuminant.

The panel surface was within the accepted 94 degree visual field of the controllers monitoring a radar. Measurements of light in foot candles at the panel and the controller position normal viewing area differed by well over the accepted factor of ten as published by Grandjean [1971] for acceptable lighting contrast in the visual field. Actual light measurements in foot candles are shown in Table VII.

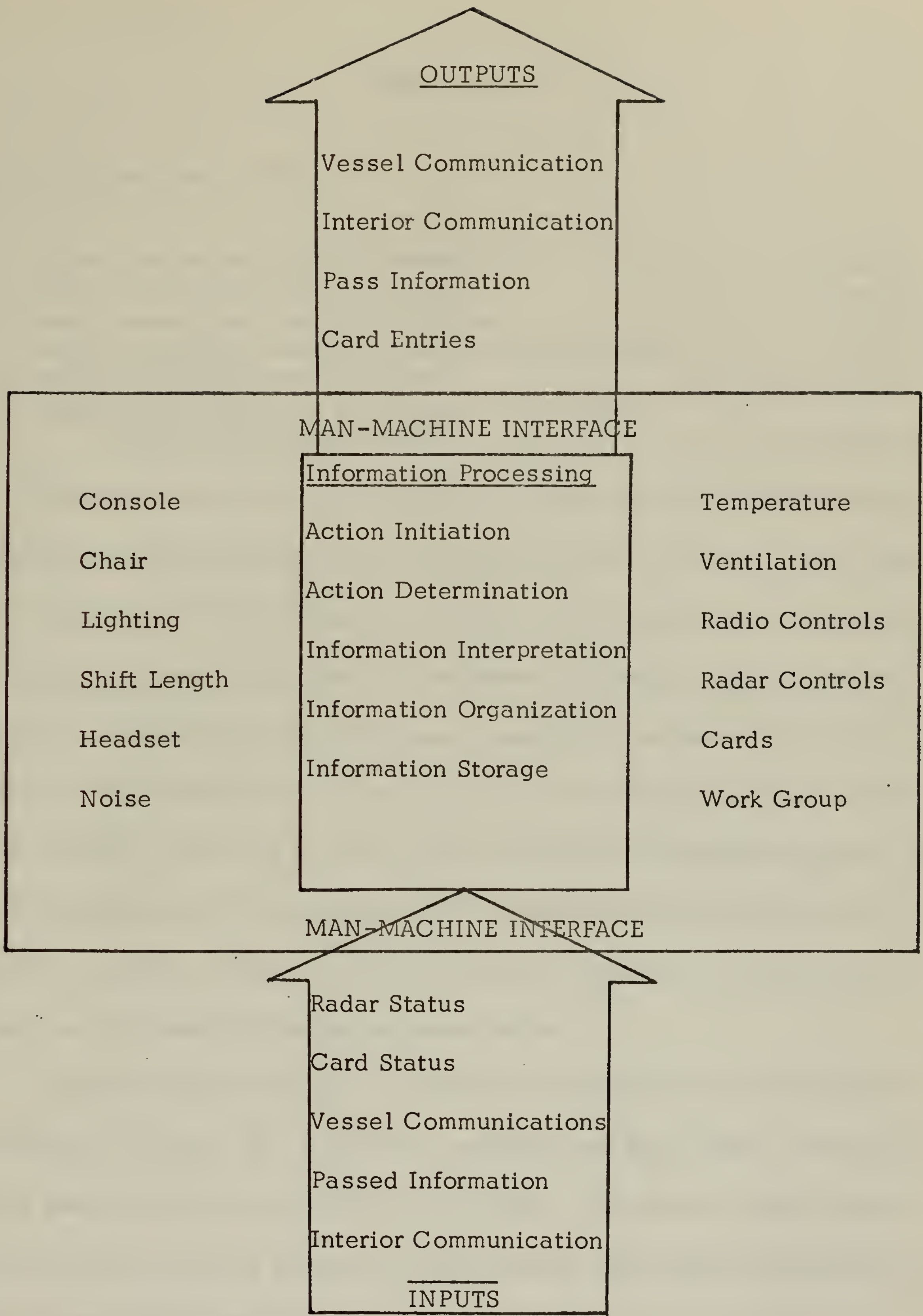


Figure 8
Sector Controller Model

TABLE VII

Light Measurements, VTSSF

Normal controller position, toward	0.020 fc
Radar screen from one inch minimum	No Reading
Radar screen from one inch maximum	0.200 fc
Normal controller position, toward maximum panel	0.700 fc
Panel illumination from one inch	1.650 fc
Ambient light, 360 degree average, room center omitting direct panel zone	0.025fc

Contrast at these levels constitutes relative glare and a very real probability of performance decrement on the part of the controller. One of the most consistent effects of fatigue in human factors literature, including visual fatigue brought on by glare, is decreased vigilance. The activity of radar interpretation and its associated capability were determined by the controllers to be both the most important and most demanding of their functions. This activity, even at peak case loads of fourteen to eighteen contacts, could best be described as a vigilance task. A study conducted by Catterson [1970] of FAA air traffic controllers performing tasks similar to VTC controllers illustrates this result of fatigue on performance.

Lighting systems designed specifically for radar rooms are suggested in detail by Morgan, et. al. [1963] , and Kraft and Fitts [1954]. These systems prevent not only glare in the visual field, but prevent signal contrast reduction from ambient light on the radar screen and indirect reflections from the screen to the operator.

B. NOISE LEVELS

Direct noise level measurements were not made in this study. Observed noise other than social conversation are system requirements. The effect of non-activity related conversation is not documented. Treatments of spurious, non-related signals in a vigilance task show conflicting results as to their effect.

C. SHIFT LENGTHS

Observed and maximum shift lengths are within bounds established for similar radar operation tasks such as shipboard operations [Woodson and Conover 1964] and Air Traffic Controllers [Fitts 1951].

D. CONTROL OPERATIONS

Equipment control mechanisms satisfy criteria established in the literature for their particular functions.

E. EQUIPMENT LAYOUT

Measurements of the physical environment of the controller were made to evaluate the suitability of equipment positioning with respect to established practice in human factors literature (Figure 9).

1. Radio Transmission Key

The foot actuated key was a bar-type covering the width of the controller position. Keying was done with either foot. The keying system for the radar controllers was moveable in relation to the radar console. These features enabled the controllers to place the system at the most comfortable position. Measurements of the relationship of the keying system to the seated operator showed a positioning in close accordance with optimum positioning suggested by Woodson and Conover [1964].

A. 95th Percentile Eye Height, Seated, Low Activity
B. 5th Percentile Eye Height, Seated, Low Activity
C. 50th Percentile Shoulder Height, Seated, Low Activity
D. Radio Frequency and Transmitter Controls
E. Radar Screen Perpendicular Viewing Line
F. Range Track Ball
G. Console Shelf
H. 95th Percentile Knee Height, Seated
I. Standard 18 Inch Chair Height
J. Observed Chair Height
K. Transmitter Key

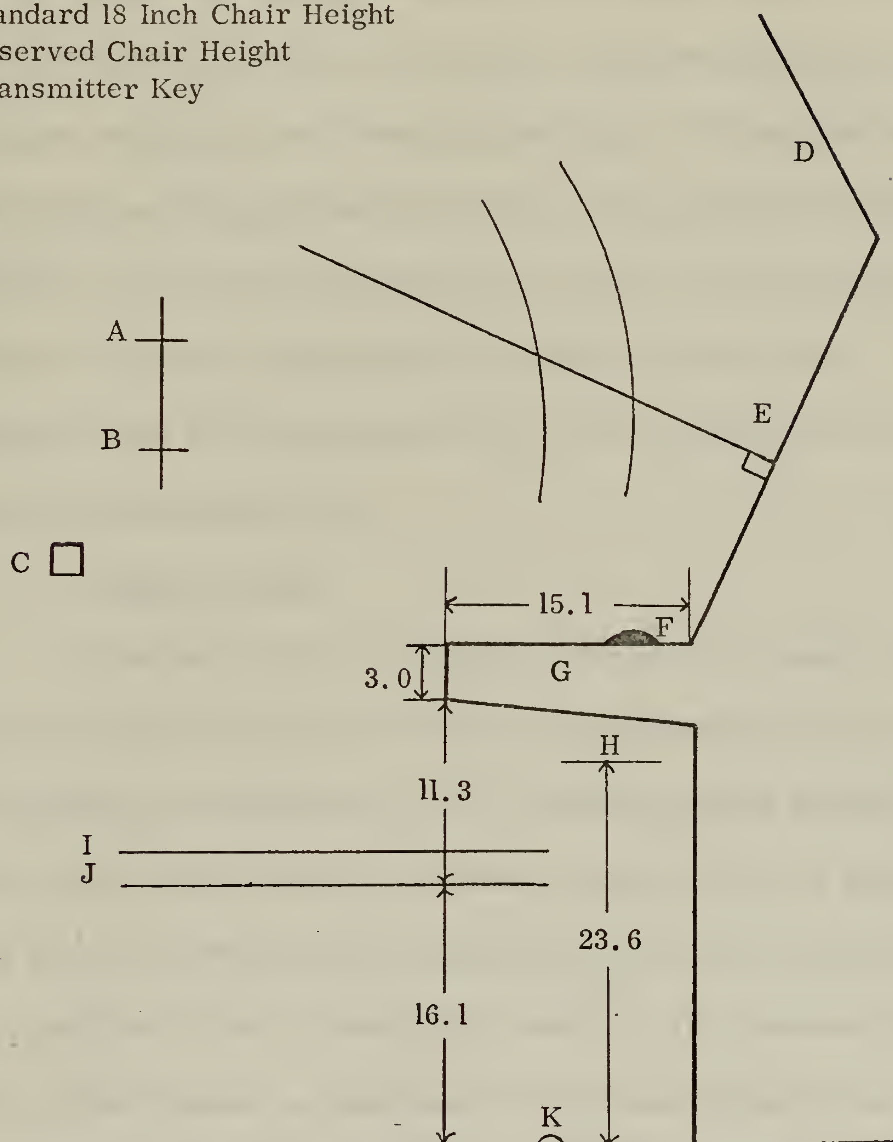


Figure 9

Radar Console Measurements (Inches)

2. Radar Console Position

Radar height, desk height and chair measurements conform to established practice and research as published by Grandjean [1971], Morgan et. al. [1963], and Woodson and Conover [1964]. A deviation not covered in the literature but observed *in situ* was the desk surface depth. In periods of high activity within a sector, insufficient space was available to perform the non-display monitoring and recording functions. These functions were rated by controllers as being in the lower third of the capability requirements, but in the center of the task demandingness ranking. This disparity was not only an indicator of general dissatisfaction with the card system, but also the clumsiness of the card arrangement on an under sized desk as mentioned in the controller comments table.

3. Radio Controls

The arcs in Figure 9 indicate the maximum reach of fifth and 95th percentile military subjects as tabulated by Woodson and Conover [1964]. The relationship of these arcs to the controller seated position points up a human design shortcoming. To change communications frequency or transmission site the controller must discontinue his visual monitoring functions, stand up and reach for the appropriate control. The necessity of leaving activities which require approximately 40 percent of controller capability to carry out an act requiring less than five percent indicates the lesser activity is out of position.

The low demandingness rating for radio control operation was due in part to ease of use of the keying system and low frequency use of the control panel.

F. VENTILATION

Exhaust ventilation and airflow were observed to be absent. The recommended [Woodson and Conover 1964] airflow for similar facilities is one-half cubic foot fresh air per minute per square foot of floor space.

G. ISOLATION

Isolation in windowless rooms with no real world visual information is covered by Catterson [1970]. This paper reported increased anxiety levels and fatigue beyond that experienced from similar activites in rooms with windows.

V. CONCLUSIONS

The analysis process of system description, activity analysis and environmental analysis for the Vessel Traffic Center affords an amount of insight into relevant human factors aspects of the system internal environment. Conclusions concerning the results of the analysis of these aspects were drawn from this information.

A. SYSTEM ACTIVITY ANALYSIS

The information contained in the activity analysis section of the study has practical implications for the managerial functions of staffing, training and operations in a VTC.

As officer personnel were primarily occupied at a supervisory positions, the controller burden was born largely by enlisted personnel. The statistically significant difference between officer and enlisted personnel in ranking of demandingness indicated more weight should be given to the enlisted ranking in system modification and design.

1. Staffing

Data concerning human capability requirements and the demand placed on the controller in performing the assigned duties should be taken into account when selecting personnel for assignment as controllers. For example, ability in monitoring and interpretation of visual display information stands out as highly desireable.

2. Training

It is important to review the activity analysis data as a guide for areas of concentration in training programs. This approach to training controllers would emphasize those capabilities most called for, and provide for more practice in those activities felt to be most demanding (difficult, restrictive, stress producing).

3. Operations

This data provides the beginnings of a basis for establishing more effective liaison between operations personnel and hardware design or layout activity personnel. The early identification of human performance dimensions can result in more efficient man-machine interface configurations. When equipment and layout designers are made aware of the capabilities called upon most heavily and of the activities and tasks which prove to be most demanding in the operational situation, they are in a position to evaluate equipment designs for the possibility of reducing the capabilities required or modifying a design or layout so as to reduce the demandingness of an activity.

Personnel performance information is also contained in the data. The information on capabilities required and the difficulty, restrictiveness, and stressfulness aspects of the controller task can serve as guidelines for development of proficiency measures.

B. MAN-MACHINE INTERFACE

Deviations from research proven standards in this area are correctable only at some monetary cost for operational systems. Attention to this area of the system in the design phase reduces the possibility of impairment of overall system capability. "One might define the goal of all human factors

works as an attempt to enhance the contribution of the operator to overall system effectiveness"[3]. The following conclusions and recommendations are applicable to VTC San Francisco only.

1. Lighting

A glare free environment of sufficient light level can be achieved by various methods and expense.

a. Controller Adjustment

Both reflected and peripheral field glare at the controller position should be reduced by turning the controller seat away from the lighted VRMS chart and viewing the radar from a non-direct angle.

b. Light Plan Adjustment

(1) A modification of the Kraft and Fitts [1954] Broad-Band-Blue System is possible with the currently installed yellow-orange filters. Indirect ambient light at present levels could be provided by a standard fluorescent fixture in a central location. This installation combined with a reduction in light from the VRMS chart should reduce glare in the VTC.

(2). Full installation of the Board-Band-Blue System with a blue light filter and VRMS chart light reduction should further decrease glare characteristics.

2. Other Areas

Modification of ventilation, radio equipment location and desk depth should be considered. No analysis was done to determine cost/effectiveness tradeoffs in the area of modifications.

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[3]Howell, W. C. and Goldstein, I.L., Engineering Psychology, Appelton-Century-Crofts, 1972.

Operator boredom under light traffic conditions could be relieved by employment of excess controllers at non-controller tasks while expanding coverage area for remaining controller(s).

APPENDIX A: DEFINITIONS

I. GENERAL

A. Vessel Traffic System (VTS). An integrated system encompassing the variety of technologies, equipment and people employed to coordinate vessel movements in or approaching a port of waterway.

B. Vessel Traffic Center (VTC). The facility from which activities of a vessel traffic system are directed.

C. VTS Element. One of a number of parts that may comprise a VTS.

D. VTS Sub-system. One or more VTS elements combined to manage traffic in a sector of a port or waterway.

E. VTS Level. The degree of sophistication of equipment and management capabilities attained by combining VTS elements into sub-systems or systems.

F. Area of Operations. The geographical limits of VTS jurisdication.

G. VTS Sector. A portion of a port or waterway with defined geographical limits.

H. Participant. Those individuals or organizations that use a VTS or otherwise use information collected by the system.

II. ELEMENTS

A. Traffic Separation Scheme (TSS). A scheme which aims at reducing the risk of collision in congested and/or converging areas by separating traffic. Audible/visual aid systems, queuing techniques, charted areas, zones and langes are combined to provide an organized flow of vessel traffic into, out of, and within a port or waterway.

B. Vessel Movement Reporting System (VMRS). A communications network linking the vessels in a VTS with a VTC.

C. Basic Surveillance. Visually monitoring vessel traffic movement in a port or waterway by means of basic radar and/or visual observations.

D. Advanced Surveillance. Visually monitoring vessel traffic movement in a port or waterway by means of advanced radar systems, low light and possibly radar transponders.

E. Computerized Collision Avoidance System. Visually monitoring vessel traffic movements in a port or waterway by means of advanced surveillance radars aided by computers for automated traffic analysis and management.

III. MANAGEMENT

A. Traffic Management. Coordinating or controlling the movement of vessels in or approaching a port or waterway.

B. Passive Management. Coordinating vessel traffic through indirect control of vessels movements by means of TSS and regulations.

C. Advisory Management. Coordinating vessel traffic by disseminating advice in the form of navigational, weather and vessel movement information.

D. Active Management. Coordinating vessel traffic through direct or positive control of vessel movements from a VTC.

APPENDIX B: SYSTEM ACTIVITY ANALYSIS QUESTIONNAIRE

Name ____________________________ Grade ______________

Capability Requirements Rating

Assume the controller task requires 100 per cent capability. Assign fractions of the 100 to the functional breakdown below, totaling 100 per cent. These fractions represent relative skill levels necessary to be a fully qualified controller. Another interpretation is that of relative demands for ability in these areas.

DISPLAY MONITORING (RADAR)	____________
NON-DISPLAY VISUAL MONITORING (CARDS)	____________
COMMUNICATIONS MONITORING	____________
RECORDING (CARDS)	____________
REPORTING (OUTGOING COMMS)	____________
INFORMATION STORAGE (MEMORIZATION)	____________
INFORMATION ORGANIZATION	____________
ACTION DETERMINATION (DECISIONS)	____________
EQUIPMENT CONTROL	____________

Activity Analysis Rating - Difficulty

DIFFICULTY - The extent to which the activity requires technical (Special, O.J.T.) training and experience for adequate performance.

Activity	Ranking
1. OPERATE RADAR	______
2. READ RADAR DISPLAY	______
3. INTERPRET RADAR DISPLAY	______
4. RECORD CARD DATA	______
5. USE CARDS AS ACTION INITIATORS	______
6. RELATE CARDS TO SCOPE	______
7. PASSING INFO/CARDS TO NEXT SECTOR	______
8. REVIEW WEATHER AND NOTICE TO MARINERS	______
9. OPERATE RADIO EQUIPMENT	______
10. KEEP SUPERVISOR INFORMED ON DEVELOPMENTS	______
11. MEMORIZATION OF INFORMATION	______
12. ANSWERING INFORMATION QUERYS	______
13. INITIATING ADVISORY MESSAGES	______
14. CONTROL RESTRICTED AREA TRAFFIC	______
15. MONITOR THE CONTROL FREQUENCY	______

Activity Analysis Ranking - Restrictiveness

RESTRICTIVENESS - The amount of attention the activity requires of a controller, thereby restricting his ability to perform other activities at the same time.

Activities	Ranking
1. OPERATE RADAR	______
2. READ RADAR DISPLAY	______
3. INTERPRET RADAR DISPLAY	______
4. RECORD CARD DATA	______
5. USE CARDS AS ACTION INITIATORS	______
6. RELATE CARDS TO SCOPE	______
7. PASSING INFO/CARDS TO NEXT SECTOR	______
8. REVIEW WEATHER AND NOTICE TO MARINERS	______
9. OPERATE RADIO EQUIPMENT	______
10. KEEP SUPERVISOR INFORMED ON DEVELOPMENTS	______
11. MEMORIZATION OF INFORMATION	______
12. ANSWERING INFORMATION QUERYS	______
13. INITIATING ADVISORY MESSAGES	______
14. CONTROL RESTRICTED AREA TRAFFIC	______
15. MONITOR THE CONTROL FREQUENCY	______

Activity Analysis Ranking - Stressfulness

STRESSFULNESS - The extent to which an activity induces a sense of subjective strain, e.g., sweaty palms, pounding heart.

Activities	Ranking
1. OPERATE RADAR	______
2. READ RADAR DISPLAY	______
3. INTERPRET RADAR DISPLAY	______
4. RECORD CARD DATA	______
5. USE CARDS AS ACTION INITIATORS	______
6. RELATE CARDS TO SCOPE	______
7. PASSING INFO/CARDS TO NEXT SECTOR	______
8. REVIEW WEATHER AND NOTICE TO MARINERS	______
9. OPERATE RADIO EQUIPMENT	______
10. KEEP SUPERVISOR INFORMED ON DEVELOPMENTS	______
11. MEMORIZATION OF INFORMATION	______
12. ANSWERING INFORMATION QUERYS	______
13. INITIATING ADVISORY MESSAGES	______
14. CONTROL RESTRICTED AREA TRAFFIC	______
15. MONITOR THE CONTROL FREQUENCY	______

Comment

Two aspects, equipment or task activities which could/should, in your opinion, be changed to increase controller effectiveness.

1.

2.

Are 1. and 2. above, or do you feel	1		2	
	Yes	No	Yes	No
A. Held as problems by more than half the controllers?	___	___	___	___
B. Problems which could have been designed out in earlier development?	___	___	___	___
C. The problem does not affect my capability, only my liking for the job.	___	___	___	___

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This paper constitues an investigation of human factors in U.S. Coast Guard operated vessel traffic system operations center in general and the San Francisco center in particular. Research involved in preparation of this thesis was accomplished by measurement, observation, job analysis by operational personnel and review of applicable human factors literature. These research steps resulted in a description of the operating system, task

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capability requirements, task-induced-demand analysis and comparison of the physical environment with published literature. Human factors aspects of the system having probable or possible detrimental effects on system effectiveness are pointed out, and quantified where possible. Experimentally proven steps to relieve these effects are presented as an aid for operational systems and designers of future systems.

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